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PRINCETON UNIVERSITY

DEPARTMENT OF
AEROSPACE AND MECHANICAL SCIENCES

FINAL REPORT TO

NASA ON FACILITIES

Grant ~~[illegible]~~-14

NGF-14

Submitted by: Harold E Burkert

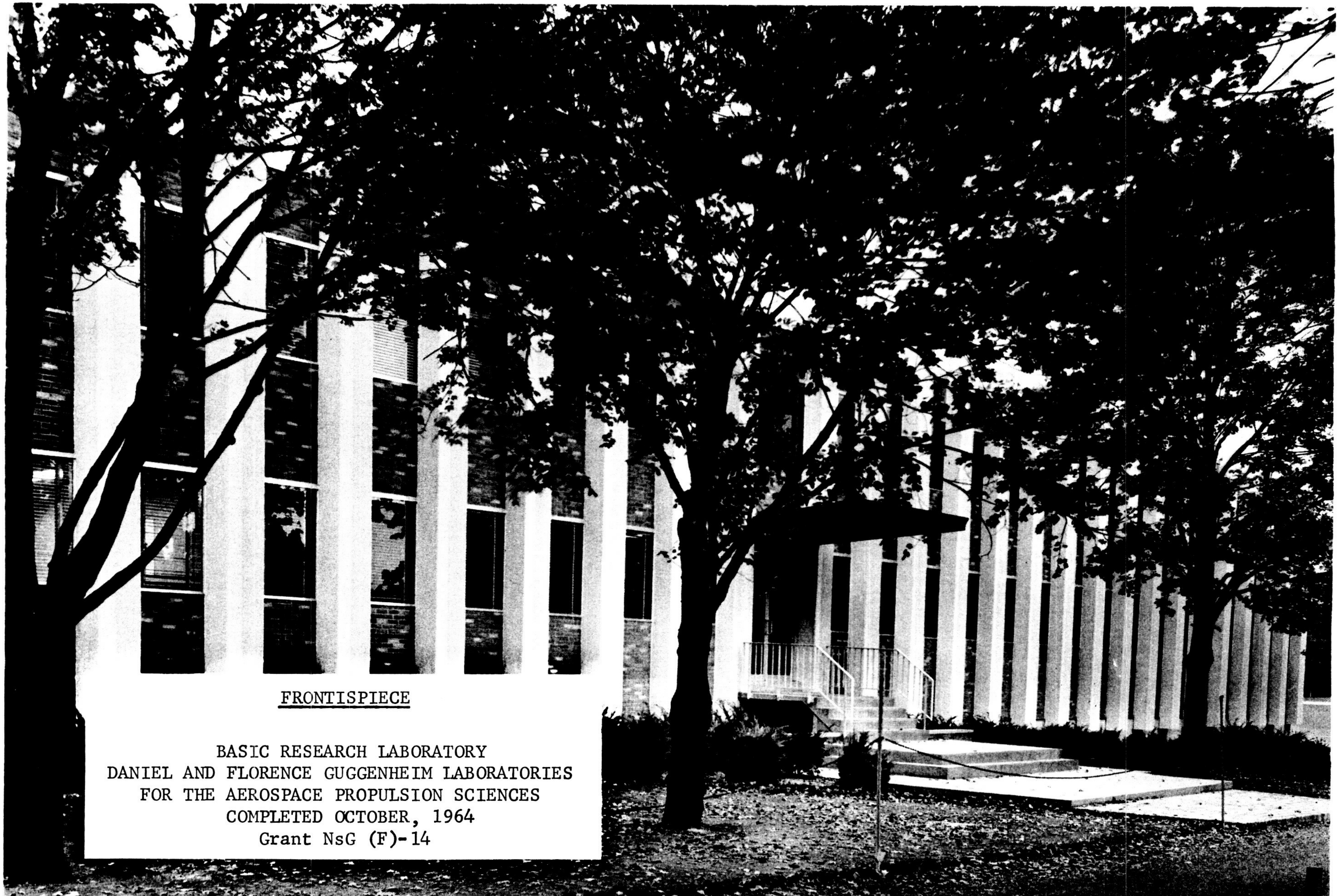
H. E. Burkert

Approved by: Jerry Grey

Prof. J. Grey

May 10, 1965

Guggenheim Laboratories for the Aerospace Propulsion Sciences
Department of Aerospace and Mechanical Sciences
PRINCETON UNIVERSITY
Princeton, New Jersey



FRONTISPIECE

BASIC RESEARCH LABORATORY
DANIEL AND FLORENCE GUGGENHEIM LABORATORIES
FOR THE AEROSPACE PROPULSION SCIENCES
COMPLETED OCTOBER, 1964
Grant NsG (F)-14

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I SUMMARY

On June 26, 1963, the efforts of Mr. J. P. Layton and Mr. R. Woodrow of Princeton University culminated in the issuance of a Grant by the National Aeronautics and Space Administration in the amount of $625,000 (Grant NsG (F)-14).

The Grant was made for construction of a Basic Research Laboratory for the Guggenheim Laboratories of Princeton University.

Previous to this Grant, Princeton University had engaged an architectural firm to design and complete working drawings for the building. Immediately following the Grant, NASA reviewed the drawings, and by mid September, 1963, bid invitations were sent out. In October, 1963, the bids were returned, and the lowest bid, added to estimates of other costs, resulted in a final turnkey budget of $750,000. The Grant plus $125,000.00 of Princeton's funds permitted construction to begin in November, 1963.

The target date for occupancy of the building was easily met and the turnkey budget was not exceeded.

As of the date of this report the building has not been formally accepted by Princeton. This will be done immediately following the final balancing of the air conditioning systems, which must wait for a few warm days.

II FINANCIAL

The realization of the subject Research Laboratory was made possible by Facilities Grant No. NsG (F)-14, in the amount of $625,000, and an additional $125,000 of Princeton University funds.

The actual costs of the building were as follows:

A.	Basic Construction	$592,885
B.	Architect's Fees (including some preliminary work on adjacent future buildings to assure continuity of planning).	52,500
C.	Site Work (including a parking lot as well as landscaping and sidewalks).	9,500
D.	Furnishings (including basic laboratory furniture and safety equipment, venetian blinds, and office furniture).	16,000
E.	Additions and changes to original contract.	71,000
		$741,885

Approximately 15 certificates for payment were submitted by the architect to the owner at various stages of construction. These certificates were all checked and approved by the architect.

Approximately $5,000.00 still remains unpaid, pending completion of the final punch list items and air conditioning balancing.

The additions and change orders to the original contract appear high, but most of these were anticipated before the contract was made. Unavoidable circumstances required the exclusion from the original bid of the electrical service to the building, the connection to the central steam main, a 200kw power service in the first level, and the partitioning of the laboratories in the building. These four additions amounted to 99% of the dollar value of all change orders.

III DESIGN

The specifications given to the architectural firm of Scrimenti, Swackhamer and Perantoni of Somerville, New Jersey, required a design which would be functional, esthetically pleasing, and flexible enough to provide for the needs of future researches. This was accomplished as follows:

The primary electric power transformers and their leads to the building were made large enough to take care of the anticipated needs for the foreseeable future.

The foundation and footings were made to accommodate future additions.

The mechanical services room was designed to accommodate equipment for future additions.

Vertical, hollow concrete columns on the front of the building became the architectural focus as well as serving as chases for mechanical services.

The building was designed basically as a two-story structure plus basement, with the laboratory area being two stories high. The steel framework was designed so that a floor can be added at the second-floor level at some future date, and the two-story laboratory can become two one-story laboratories.

The main roof structure was Virendeel girders allowing straight-through access of experimental ducting and piping.

Certain areas in the concrete floors were restricted from being used by the mechanical contractors for piping, electrical conduits, etc. This was done so that reasonably large holes can be cut into the floor without interfering with services to accommodate future requirements for experimental apparatus.

Certain areas on the basement ceiling were reserved for future experimental services such as large piping, conduits, etc.

The entire building was designed to be air conditioned, with provisions for maintaining minimum humidity conditions in the laboratory area. One of the reasons for this was to prevent the static electricity buildup which can occur in low-humidity atmospheres.

Concrete haunches around the floor beams were designed to minimize vibration transmission. The mechanical services room floor was completely isolated for the same reason.

The electric distribution throughout the building was designed to prevent voltage drops in one laboratory due to an experiment in another laboratory. This was accomplished by isolating the "building electric" circuits (lights, office outlets, fans, mechanical pumps, etc.), and providing separate circuits, direct from the secondary transformers, for each laboratory for the exclusive use by that laboratory for experimental apparatus.

IV <u>CONSTRUCTION</u>

The firm of William C. Ehret of Trenton, New Jersey was awarded the contract to build the Basic Research Laboratory.

The responsibility for job supervision was with the architect, although Princeton University maintained a clerk-of-the-works full time during construction. This person contacted only the architect, however, and had no authority to control the contractor. This chain-of-command management proved to be very desirable.

The cooperation of the contractor in all cases was very good, and no serious problems concerning construction arose. The job was completed on time, and at this date only a small punch list remains to complete the contract in full.

The punch list at the time of occupancy was relatively small due to an agreement between the architect, the contractor, and Princeton University making it possible to present and complete normal punch-list items during construction.

The urgency to occupy the building for the Fall term of 1964 made it necessary to negotiate the contract without a location for the source of primary power, a central steam main connection, and partitioning of the Laboratory area. These items were decided after construction was well under way and were accomplished as change orders (see Numbers 5, 6, 7, below).

The following is the complete list of change orders:

C. O. No.	Date	Nature of Change	Amount
1	11/20/63	Omit Performance and Maintenance Bond	$ (3,987.00)
2	12/2/63	Substitute Extruded Lower Penthouses	(160.00)
3	2/12/64	Revise Women's Toilet 1-04	N/C
4	4/2/64	Install Plumbing Piping under Basement Slab for Future Aid	1,937.00
5	4/16	General Revisions of Office & Laboratory Areas to provide active space in open areas	42,292.00
6	4/24	Revision to Underground Steam Service and connections at existing steam tunnel	9,706.00
7	4/30	New Underground Electric Services	10,732.00
8	6/30	Adjustment to Specified Brick Allowance	(315.00)
9	7/23	Omit Aluminum Plaque and Door Signs	(165.00)
10	7/23	Credit for Rock Excavation Allowance (none encountered)	(1,200.00)

C. O. No.	Date	Nature of Change	Amount
11	8/27	Stiffeners for Certain Long Partitions	300.00
12	12/1	Accoustical Lining for Four Air Handling Units	360.00
		Net Total	$71,154.00

V USE OF LABORATORY

Completion of the Basic Research Laboratory will, for the first time, allow the Guggenheim Laboratories to perform research functions with maximum effectiveness at significant levels of activity in support of the national need for highly trained personnel and intensified fundamental research efforts in the Aerospace Propulsion Sciences. At the outset, this building will house four of the primary researches being conducted at the Guggenheim Laboratories.

The first, under Professor Martin Summerfield, is the Solid Propellant Research Group. The areas of interest in this group are Solid Propellant Ignition Research, Steady-State Combustion Mechanisms, and Non-Steady Combustion. Research on steady-state combustion can be related to the effective development and proper utilization of high energy solid propellants. Studies of the mechanism of combustion and of the extinguishment of combustion are also related to the problems of throttleability and of pulsed operation of solid propellant motors. Ignition research will contribute to a better understanding of the overall ignition process of solid propellants.

The second is the Nuclear Propulsion Research Laboratory under Professor Jerry Grey. The major study in this area is to determine both analytically and experimentally the mixing and heat-transfer characteristics of hot, partially ionized gas. This task, already partially accomplished, will have direct significance to all gaseous-core nuclear rocket concepts as well as subsidiary applications in arcjet propulsion and magnetohydrodynamic power generation. A second research will be of feasibility consideration in the liquid core nuclear rocket concept by experiments on gas-liquid interactions. A third study will be concerned with establishing feasibility of the principle of supersonic nozzle heat addition as a major performance augmentation technique for conventional solid-core nuclear rockets. Also, a program which is now being formulated will determine analytically the optimum mission characteristics, reactor and engine configurations, and major problem areas of non-conventional solid-core reactors.

The third is the Electric Propulsion Research Laboratory under Professor Robert Jahn. Housing this group in the new Basic Research Laboratory will allow them to continue their research by developing and operating a series of devices for the generation of highly symmetrical and reproducible gaseous discharges. It will allow continuation of the experimental and theoretical studies of the large radius pinch discharge apparatus, to extend the studies to circuits of very low external inductance, and to extend the studies to such other discharge geometries which are predicted by the results of the above tasks. Also, a study of the effect of exhaust orifices on the discharge and acceleration characteristics will be undertaken.

The fourth group is the Combustion of Metals Laboratory under Professor Irvin Glassman. This research concerns itself with the relation of the melting points of metals and their oxides and oxide characteristics to the combustion mode of metals. A detailed understanding of the burning of metals is certain to be of increasing significance in advanced solid

P R I N C E T O N   U N I V E R S I T Y

Department of Aerospace and Mechanical Sciences
School of Engineering and Applied Science

The Daniel and Florence
Guggenheim Laboratories
for the
Aerospace Propulsion Sciences

BASIC RESEARCH LABORATORY
CORNERSTONE LAYING

SATURDAY, OCTOBER 24, 1964
11:00 A.M.
THE JAMES FORRESTAL RESEARCH CENTER
PRINCETON, NEW JERSEY

The Basic Research Laboratory was
designed by the architectural firm of
Scrimenti, Swackhamer and Perantoni under the
personal direction of J. F. Perantoni '45.

Construction was by W. C. Ehret, Inc.
with James Ferguson as Project Engineer.

Project representatives were:
R. Johnstone and S. Frothingham for the University
J. H. Wallace Jr. and R. Osborne for the Forrestal Research Center
H. Burkert and G. Seitz for the Guggenheim Laboratories

Dr. G. Edward Pendray, Personal Representative of the Hon. Harry F. Guggenheim, President of the Daniel and Florence Guggenheim Foundation, will present greetings on behalf of the Foundation following the address of Dr. Homer E. Newell.

CORNERSTONE LAYING CEREMONY

WELCOME

Courtland D. Perkins

Chairman, Department of Aerospace and Mechanical Sciences

GREETINGS ON BEHALF OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Homer E. Newell

Associate Administrator for Space
Science and Applications

✧

PRESENTATION ON BEHALF OF THE NATIONAL
AERONAUTICS AND SPACE ADMINISTRATION

Raymond L. Bisplinghoff

Associate Administrator for the
Office of Advanced Research and Technology

CONVEYANCE OF GOLD KEYS

J. Frank Perantoni

Architect

ACCEPTANCE ON BEHALF OF
PRINCETON UNIVERSITY

Robert F. Goheen

President

✧

CORNERSTONE SETTING

President Goheen

AND

J. Preston Layton

Member, Guggenheim Laboratories Faculty Committee

PRAYER AND BENEDICTION

Ernest Gordon

Dean of the University Chapel

GUGGENHEIM LABORATORIES FACULTY COMMITTEE

Luigi Crocco
Irvin Glassman
Jerry Grey
Wallace D. Hayes
Robert G. Jahn
J. Preston Layton
Martin Summerfield

and liquid chemical rockets and other propulsion methods and, in addition, of importance in atmospheric reentry of various spacecraft from both geocentric and heliocentric orbits.

In addition to the above laboratories, this building gives office space to three professors, twenty-three students, and staff members, for a total of forty-six persons.

The design of the building makes it possible to expand its use to approximately seventy-five persons and up to six more laboratories in the future with only minor additions.

VI <u>CORNERSTONE LAYING CEREMONY</u>

A major expansion in engineering education at Princeton University was signaled on Saturday, October 24, 1964 by the formal cornerstone-laying of a new $750,000 Basic Research Laboratory of the Daniel and Florence Guggenheim Laboratories for the Aerospace Propulsion Sciences. The three-story building was financed in large part by a facilities grant from the National Aeronautics and Space Administration as part of its broad program of support for higher education in science and technology.

In their addresses to the assembled faculty and guests, Dr. Homer E. Newell, Associate Administrator of NASA for Space Sciences, and Dr. Raymond L. Bisplinghoff, Associate Administrator of NASA for Advanced Research and Technology, emphasized NASA's interest in advancing technical education in this country as a means of insuring the continuation of the strong position of the United States in scientific space exploration and in the development of practical space systems. The complete texts of these addresses appear on pages 12 and 13 of this report. Dr. G. Edward Pendray, representing the Guggenheim Foundation, reviewed some of the early events in our history of rocketry which led to the development of the present national space program, pointing out the major roles played by several members of the assemblage.

President Robert F. Goheen, in accepting the gold keys to the new building from Architect J. Frank Perantoni (Class of 1945) on behalf of Princeton University, recalled the pioneering steps taken by the University when, in 1947, it started a program of graduate education and research in jet propulsion in the Engineering School, and also the far-sighted step taken by the Daniel and Florence Guggenheim Foundation when it granted the University in 1949 the initial funds to launch the Guggenheim Jet Propulsion Center at Princeton's James Forrestal Research Center. The full text of President Goheen's address is given starting on page 17 .

Following the closing benediction and a buffet luncheon, the guests toured the new Basic Research Laboratory and other existing Guggenheim Laboratories research facilities, where the graduate students described their research programs in detail.

A. Address by Dr. Homer E. Newell, Associate Administrator for Space Science and Applications, National Aeronautics and Space Administration, Washington, D. C.

(Dr. Newell acknowledged Professor Perkins' welcoming remarks and introduction, and gave introductory salutations acknowledging the presence of President Goheen, Dean Brown (Dean of Faculty), Dean Elgin (Dean of Engineering, other distinguished guests, and faculty members. He extended greetings _in absentia_ from Mr. James E. Webb, Drs. Dryden, Seamans, and Smull, and the many other staff members in NASA who have contributed so much time, thought, and talent to the success of this unique undertaking).

On behalf of NASA, I am delighted to have this opportunity to express appreciation to the members of the board of trustees and the University staff for their concerted actions which were so vital to the acquisition of these new facilities. We recognize the obligations which were assumed by acceptance of the grant providing a share of the funds required, and we have the utmost confidence that Princeton will meet these obligations in full measure during the ensuing years.

It has been said that propulsion is one of the keys to the successful exploration of space. We believe this for obvious reasons, but we also believe that some of the greater challenges of space exploration can be met only with the knowledge resulting from basic research such as is being done now, and will be continued by scientists here in the Guggenheim Laboratories. Besides the engineers who design spacecraft and the astronauts who fly them, we have a continuing requirement for the research which will make a substantial contribution to the expansion of human knowledge and phenomena occurring in the atmosphere and in outer space. Along these lines, NASA's need for knowledge affecting the design of aerospace propulsion systems is a matter of record, and we are deeply indebted to the scientists here at the Forrestal Center who have pioneered this field.

From our viewpoint, we see here today the first results of an exercise in mutual confidence. Confidence of Princeton in a partnership with NASA which will preserve and strengthen the University's research environment; confidence of all of us in the intellect and creativity of the scholars who will distinguish this laboratory for many years to come; and particularly our confidence in Professors Crocco, Grey and Layton and their associates who will be using these new laboratories.

B. Address by Dr. Raymond L. Bisplinghoff, Associate Administrator for Advanced Research and Technology, National Aeronautics and Space Administration, Washington, D. C.

Professor Perkins, President Goheen, Ladies and Gentlemen. I have followed closely the building which we dedicate this morning because of its close association with NASA's Advanced Research and Technology program. I know of no new building anywhere that can exert a greater influence on the future of this program. I say this because you will be occupied here with improving the effectiveness of two of the most important ingredients of this program; propulsion and energy conversion devices and people. Let me amplify this statement.

First, let us take a few seconds to examine the incredible steps that man is taking in space. We are told that the Great Pyramid of Egypt was used as an astronomical observatory before it was converted into a tomb. The technology of that period, about 27 B. C., permitted man to ascend nearly 500 feet above the floor of the desert. By the early 1960's some 47 centuries later, give or take a few generations, man had extended his ability to ascend to a low Earth orbit, an improvement by some three orders of magnitude. By 1970 we are confident that we will command the space occoupying a concentric sphere extending from the surface of the Earth to the orbit of the Moon, an additional three orders of magnitude improvement. But we are also calculating our chances of leaping beyond the Moon to the planets, still another three orders of magnitude increment.

Each successive leap into the new space beyond demands a vast growth in the technology -- a geometric progression in growth. What are these technologies? They are principally propulsion and energy conversion, materials, guidance and control, and communications. It can be recognized that the steps in space from Earth to Earth - orbit and Earth-orbit to Moon rest on essentially the same kinds of technology. They are familiar: chemical energy conversion, relatively common engineering materials, guidance and control systems generally consistent with aircraft and ground applications, and microwave communications. However, the step from Moon to planets demands performance and reliability measured in orders of magnitude beyond the previous steps. New levels of technology will be needed. Nuclear rockets and energy conversion devices are needed to achieve the high gas temperatures which will be required to propel our vehicles and provide electrical power. New refractory materials must be found that will not burn or oxidize, that are compatible with new propellants and that are stable in the presence of high vacuum and radiations of space. New control sensors at least two orders of magnitude more sensitive than existing sensors must be devised. Conventional microwave communications need to be improved or replaced, possibly by lasers, in order to raise transmission bit rates from the planets to the Earth to an acceptable level. All of these new devices, most of which are in early stages of research or development, must achieve eventually longer life-times, higher reliabilities and lower specific weights than have heretofore been demonstrated. Whenever I think about the incongruence of the complexity-reliability requirements which are presented by future space hardware, I am reminded of the admonition given several years ago by Vannevar Bush to a graduating class of engineers. "You are entering your profession in an age of reliable complexity. My generation made it complex and it will be up to yours to make it reliable." But this is the price that must be paid to penetrate the far reaches of the solar system. The highest priced of the several parts and the key to the success of all are the propulsion and energy conversion devices. For example, over half the resources of NASA's advanced research and technology program is invested in this area.

In spite of all that I have said about the dependence of our future space program on propulsion and energy conversion advancements, your principal contribution to the program will be new people. It is important to recognize here that the needs are for quality and not quantity. There is no shortage of scientists and engineers. There is only a shortage of those capable of working at the boundaries of the newest technologies such as nuclear propulsors and electric power generators, advanced chemical engines, magnetohydrodynamic and thermionic energy converters, and advanced fuel cells. The majority of applied scientists and engineers are simply unable to contribute effectively to these difficult programs where there is little or no accumulated body of knowledge. The leaders of these programs within the NASA laboratories have experienced a changing professional life which is, I believe, typical of the future lives of today's students. Some entered propulsion technology in the late 1930's and researched reciprocating engines. Then, rather suddenly reciprocating engine research dwindled. To succeed they were compelled to make of themselves productive researchers in gas turbine technology. Presently, gas turbine research gave way to chemical rocket research. Now they are turning to nuclear propulsion, electric propulsion and magnetohydrodynamic energy conversion. Within a quarter of a century, well within the average professional life-span, they have been compelled to adapt to three or four new kinds of technologies. Only a few have succeeded. Most have been unable to make so many changes.

It is not hard to discern some of the qualities which enabled the successful ones to adapt to new professional directions. First, certain qualities of character are required. It is all too easy to turn from researcher to administrator after the first professional cycle is exhausted. A necessary condition, however, for sustained success is a thorough grounding in science and mathematics. But this in itself is not sufficient. There is required, also, the habits of thought needed to proceed from theory to synthesis to practical conclusion. A balanced combination of deep scientific knowledge with creativity is not often found nor easily taught. Most students are unable to develop in both directions. The creative student is frequently broken in spirit or eliminated by the conventional academic system. As I see it, a more effective marriage between science on the one hand and creativeness in propulsion technology on the other is at the heart of the challenge to the faculty and staff who will occupy this building. Aerospace propulsion represents, in fact, one of the finest examples of the modern interdisciplinary technologies. All of the physical sciences are brought to bear in a fundamental way in support of a creative process. We find in the classroom and thesis work of Summerfield, Crocco, Glassman, Grey, Jahn, Harrje, Layton and others on the Princeton staff, examples of the country's very best efforts to wed science with craftsmanship.

As Dr. Newell mentioned earlier, we are pleased in the NASA to be able to contribute to your important work. President Goheen, it is my privilege to declare on behalf of NASA that this building is yours.

C. Address by President Robert F. Goheen

Professor Perkins, distinguished guests, members of the University --

It is a great pleasure for me to participate in this morning's ceremony and to accept, on behalf of the University, this splendid addition to our research laboratories. I am happy that so many of you can be with us today and that I shall have an opportunity to express to a number of those responsible for this laboratory our great gratitude for their faith and assistance.

This new Basic Research Laboratory, financed in substantial measure by NASA and a part of the Guggenheim Laboratories here in the James Forrestal Center, constitutes a good example of the way in which universities, private philanthropy and the federal government can work effectively together to add to the country's educational resources and advance its strength.

The name of Guggenheim has been linked for long decades with aeronautical and - - more recently - - astronautical pioneering. It conjures up memories of Charles Lindbergh and James Doolittle, and calls to mind the researches of Robert H. Goddard, as well as Guggenheim Laboratories at several American universities. Here at Princeton, Guggenheim fellowships and the congeries of facilities made possible within The Daniel and Florence Guggenheim Laboratories have helped place this university in the front rank of those institutions carrying forward aerospace propulsion education.

As with the Foundation, the role of the federal government in this "educational trinity" is broader, and more meaningful, than that of simply providing facilities and equipment. This year, for instance, federal grants and contracts are providing the means whereby some 35 graduate students are carrying forward dissertation research here in the Guggenheim Laboratories, while 10 undergraduates are likewise being enabled to pursue their senior theses or equivalent study projects: On this count Princeton is grateful indeed to the Office of Advanced Research and Technology of NASA, the Office of Scientific Research of the U. S. Air Force, the Office of Naval Research, and other research-sustaining agencies. University education, combining effective teaching with original research, would not be possible on this high level in the experimental sciences and engineering without such partnership with government.

This new element in Princeton's Guggenheim Laboratories calls attention to significant changes that are taking place at Princeton, and elsewhere, in engineering education at both the graduate and undergraduate levels. Dramatic shifts, with ever-mounting emphasis on the scholarly and scientific aspects of engineering, are vivid in the entire aerospace engineering field, and especially in the propulsion area on which our thoughts are centered this morning.

The emergence of exciting and challenging new fields of engineering science, transcending the traditional divisions of engineering, are bringing together branches of pure science and mathematics in new and potent ways. In propulsion, for example, we can point to rocket propulsion as a combination of physics, physical chemistry, aerodynamics, and chemical engineering; and in electric propulsion we see the combination of electrodynamics, fluid mechanics and chemical physics. Classical concepts are going the way of the Model T, and new concepts are being evolved to meet new needs.

In this surging, conjoined, forward thrust of scientific inquiry and engineering practice, complex experimental and test facilities have become essential parts of the overall educational program of universities. (We are assembled in what is a relatively quiet and contemplative "building" but nearby is one of the finest supporting arrays of propulsion and combustion apparatus available for purely educational purposes anywhere in the United States.)

We at Princeton are not concerned with growth for the sake of growth; we are sensitive to the rising number of highly qualified applicants and to the rising demands for new knowledge; and they mean we must shoulder new and enlarged responsibilities while holding to our commitment to high quality. In this connection, it is interesting to note that the Department of Aerospace and Mechanical Sciences has the largest enrollment of graduate students of any department in the University (e.g., 123 compared with Physics' 103) and that the segment of the Department's enrollment which is focused on the propulsion sciences, approximates the average enrollment for many of our departments.

Now, to Drs. Bisplinghoff and Newell, and through them, to the entire leadership of NASA, I want to express our gratitude for their understanding support and their generous views on the role Princeton is playing in the space program. And I hope that you, Dr. Pendray, will convey to Mr. Guggenheim our sense of appreciation for his heartening interest and concern. I also want to express warm thanks to those who have actually designed and put together this fine laboratory: the architectural firm of Scrimenti, Swackhamer and Perantoni, and the construction firm of William C. Ehret, Co. You have done an outstanding job, and it should be here recorded that the Basic Research Laboratory has actually been completed ahead of schedule.

I do hope that all visitors will avail themselves of the chance to tour this new headquarters for the Guggenheim Laboratories and will come to share the delight many of us feel in this building. I can assure you that this is a memorable morning for all of us at Princeton.

The cornerstone was officially laid by President Goheen and Mr. J. Preston Layton of the Guggenheim Laboratories Faculty Committee, who was in good part responsible for the existence of the new Laboratory (see photograph on page 41). President Goheen then read a list of the cornerstone contents:

1. Copy of Press Release announcing the Cornerstone-Laying Ceremony
2. Copy of Ceremony Program
3. Photograph of Building
4. Guggenheim Fellowship Announcement Brochure
5. List of theses in progress
6. Photograph of Staff Members

7. Copy of 1964 Report to Guggenheim Foundation

8. List of sponsored researches in progress

9. Edwin G. Baetjer II Colloquia Announcement (1964-1965)

10. Princeton University Weekly Bulletin (October 19 to 25, 1964)

11. Copy of New York Times

12. Copy of Princeton Town Topics

13. List of personnel - Guggenheim Laboratories

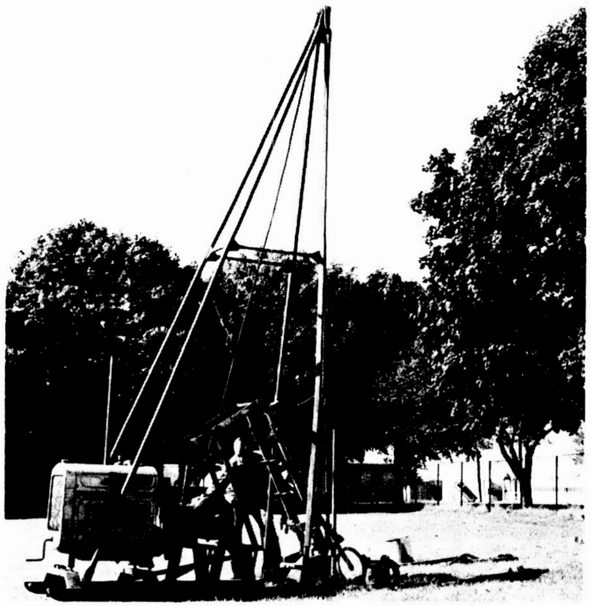
14. List of contractors, engineers and architect. Date started and completion date. Approximate cost of building.

15. Invitation to Cornerstone-Laying Ceremony

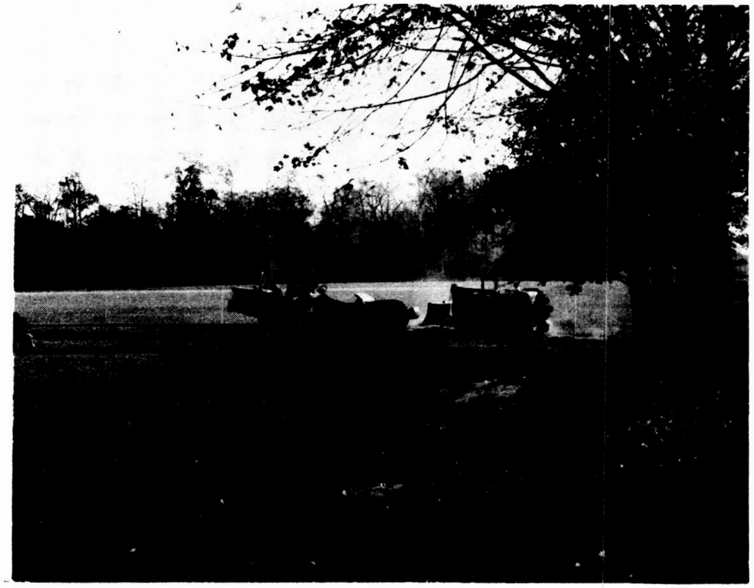
16. Astronautics and Aeronautics, October 1964 Issue

17. AIAA Journal, January 1963 Issue

18. "Space Flight Report to the Nation," Edited by J. Grey and V. Grey, Basic Books, N.Y., 1962



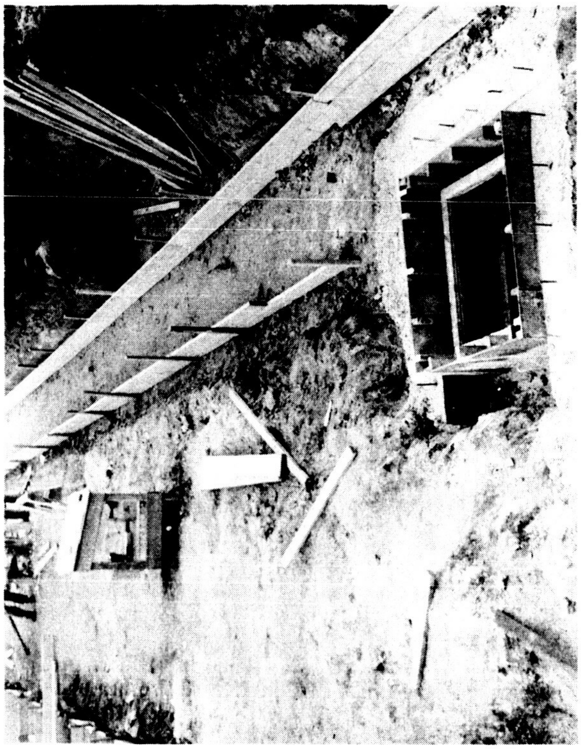
TAKING EARTH BORING



EXCAVATION BEGINS

EXCAVATION COMPLETED AND CONCRETE FORMS FOR FOOTINGS IN PLACE

CONCRETE FORMS



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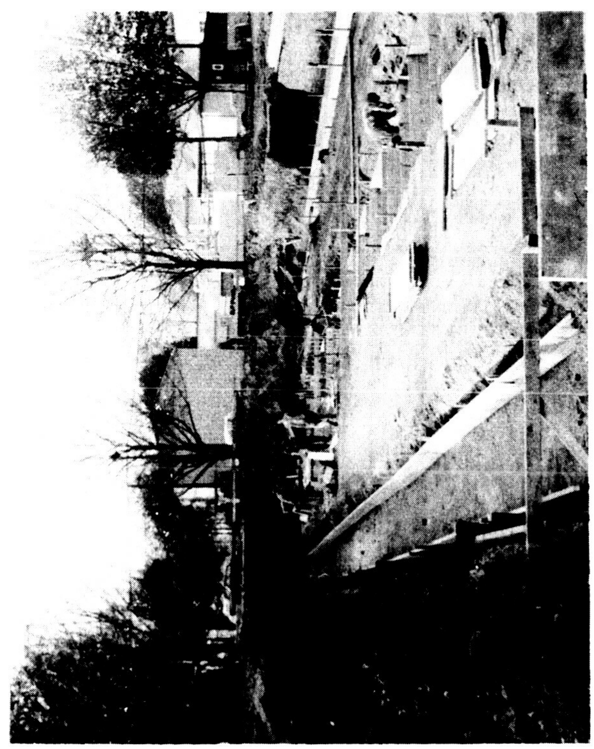
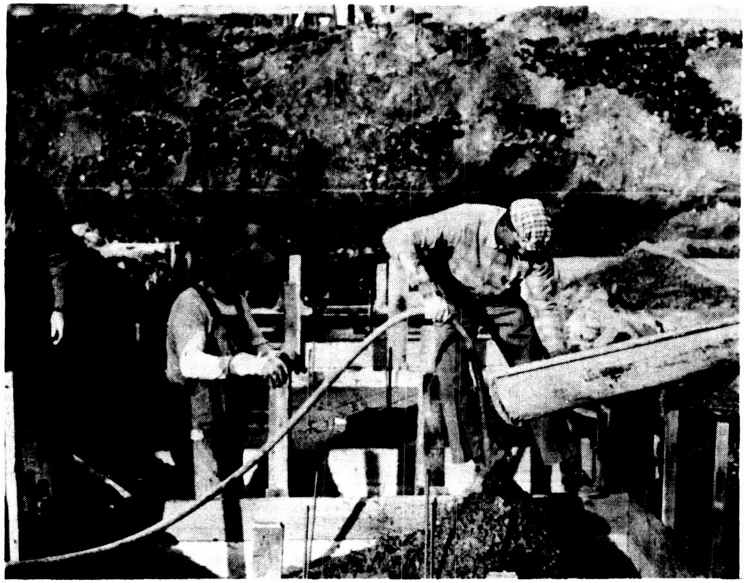


CONCRETE FORMS

CONCRETE FOOTINGS BEING POURED



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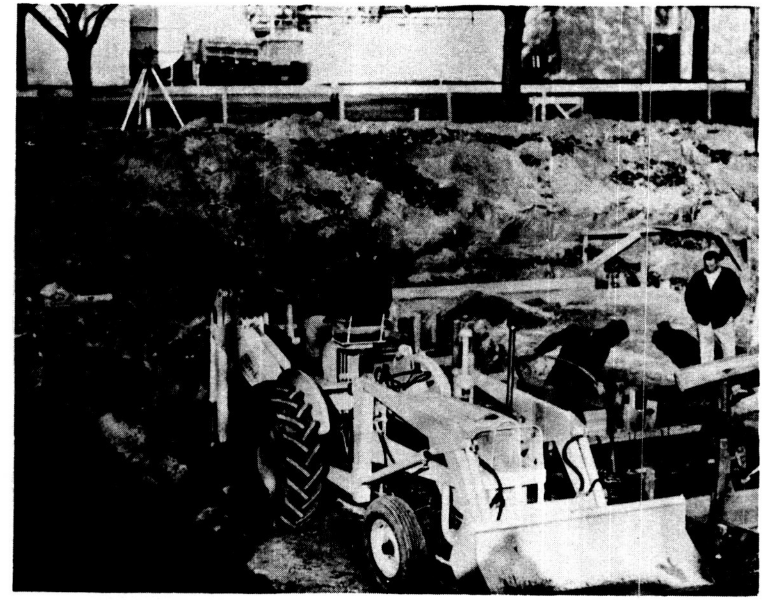
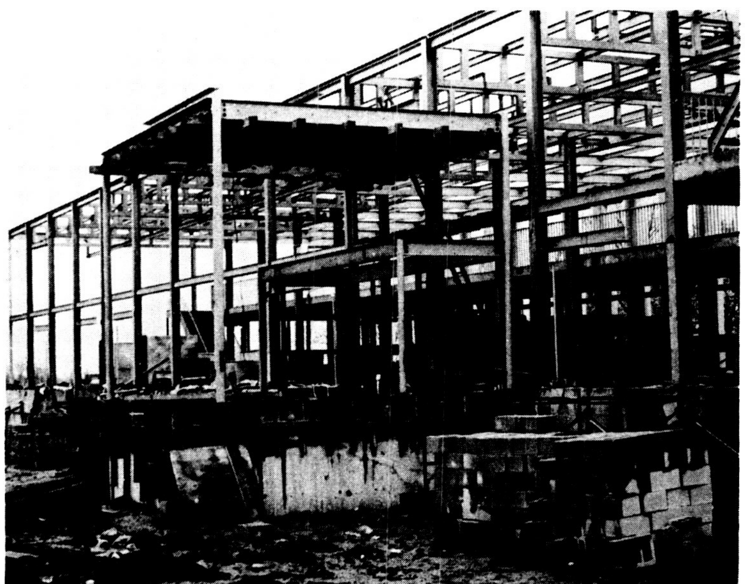
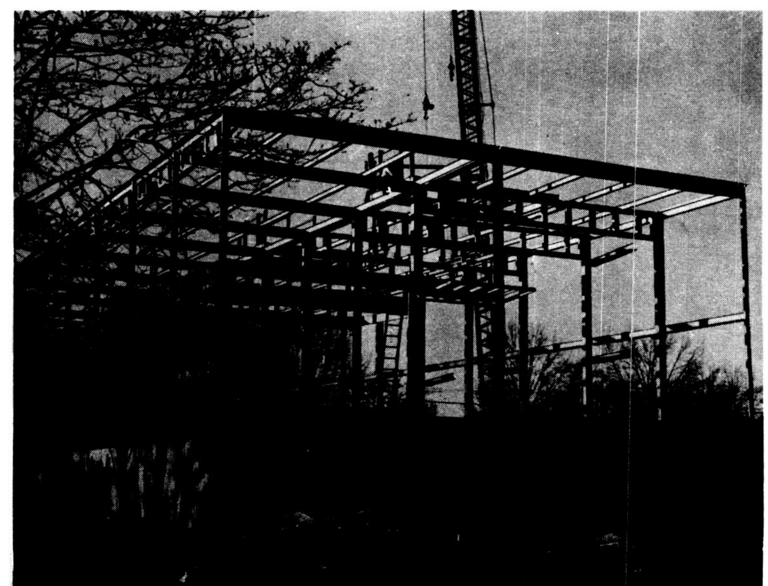


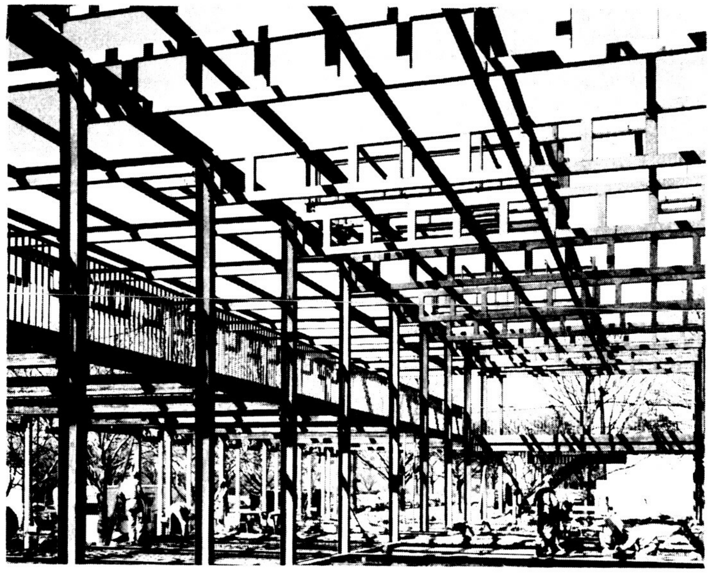
EXCAVATING FOR PLUMBING LINES



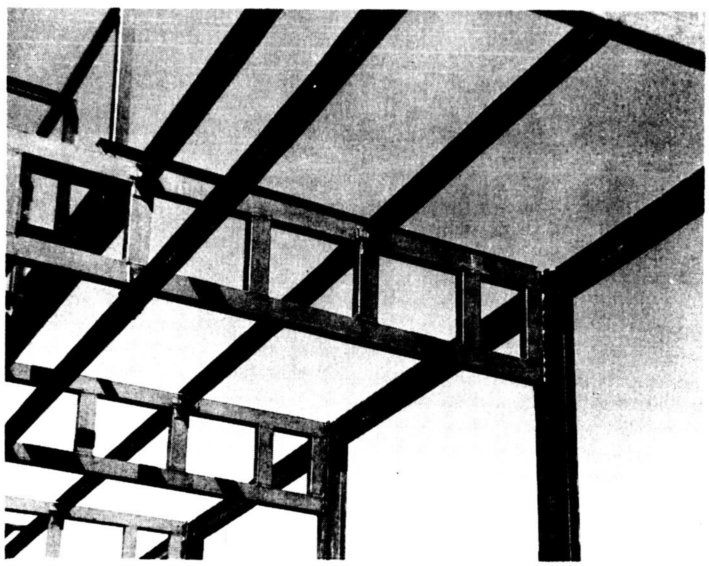
STEEL FRAMEWORK VIEWED FROM NORTHEAST



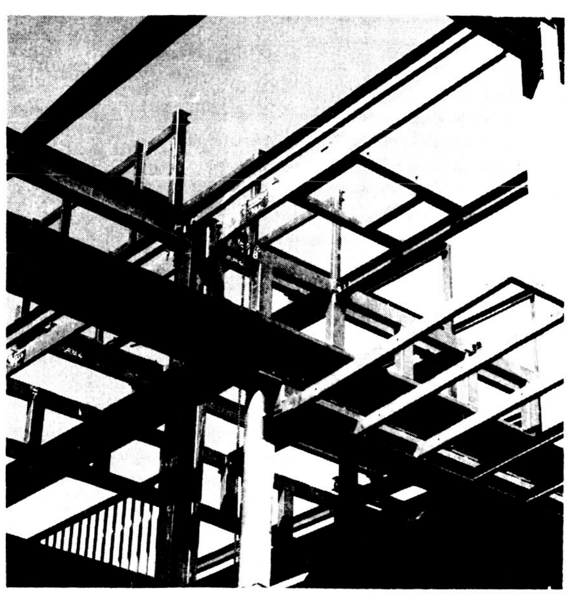
STEEL FRAMEWORK VIEWED FROM SOUTHEAST



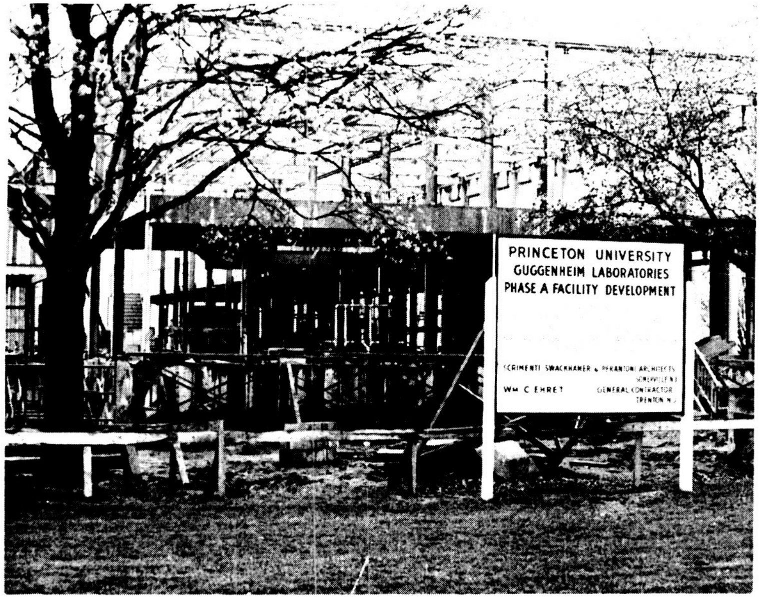
STEEL FRAMEWORK



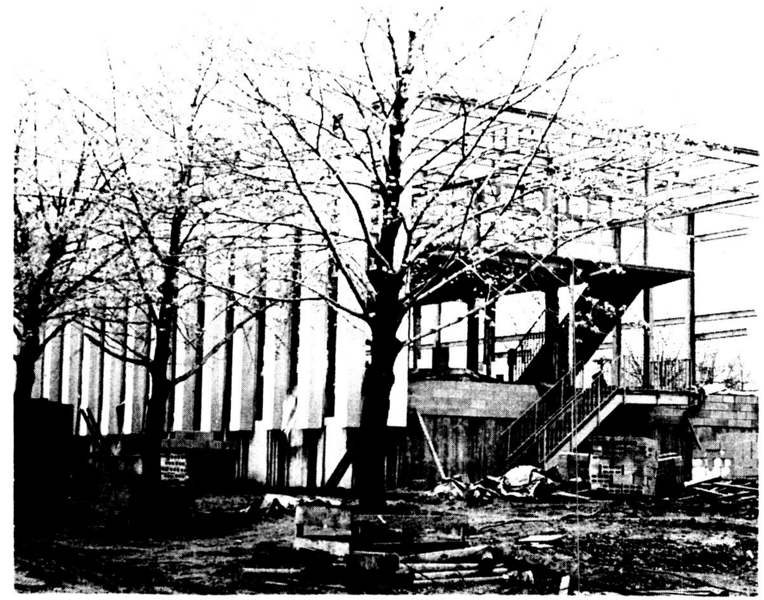
VIEW OF VIERENDEEL TRUSSES



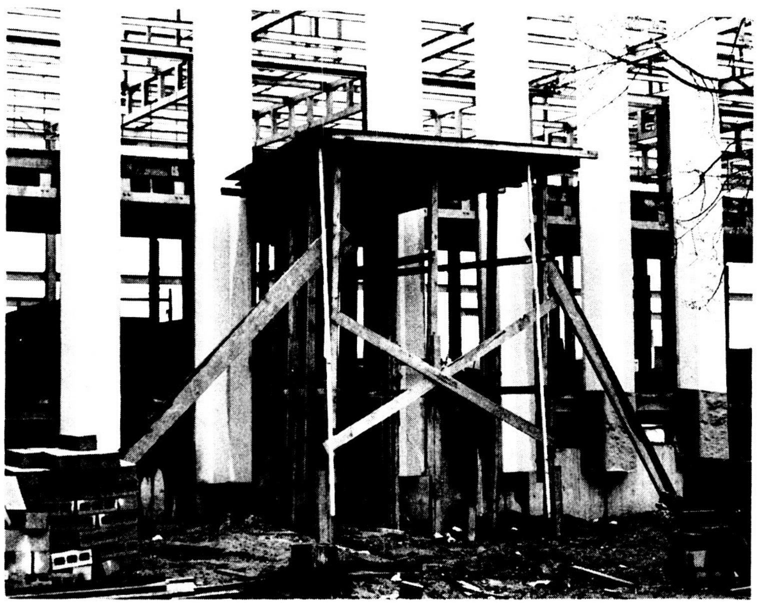
STEEL FRAMEWORK



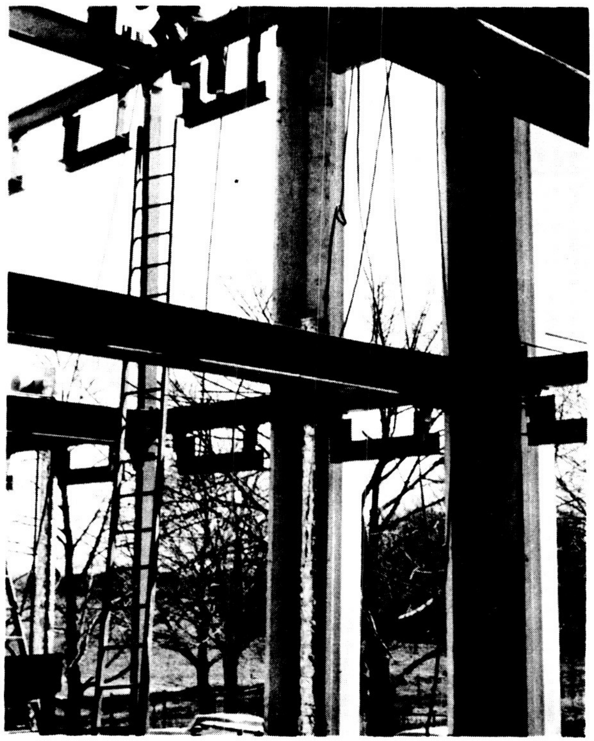
STEEL FRAMEWORK VIEWED FROM WEST



VIEW FROM SOUTHEAST SHOWING VERTICAL
CONCRETE COLUMNS IN PLACE



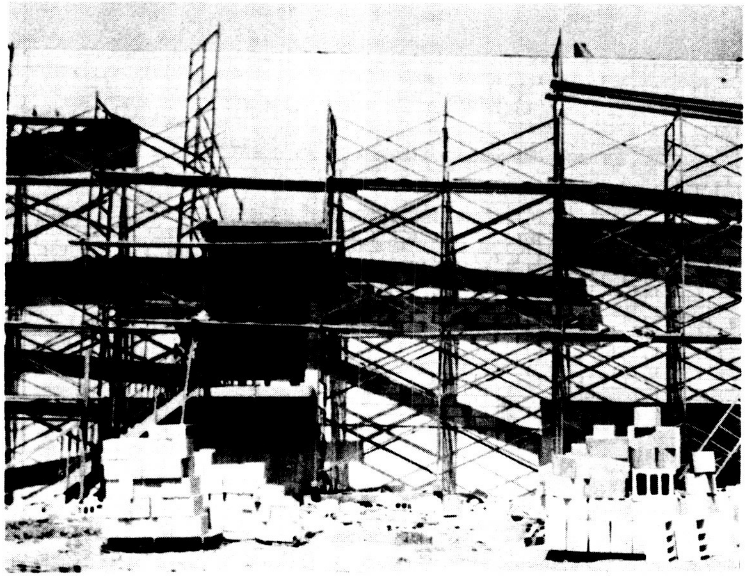
VERTICAL CONCRETE COLUMNS IN PLACE



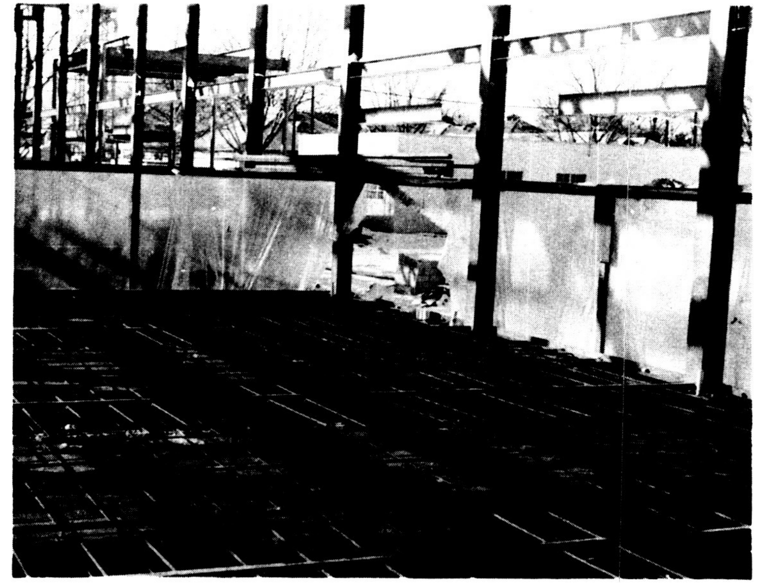
INTERIOR VIEW OF CONCRETE COLUMNS SHOWING CHASES FOR SERVICES

BRICKWORK ON FRONT OF BUILDING

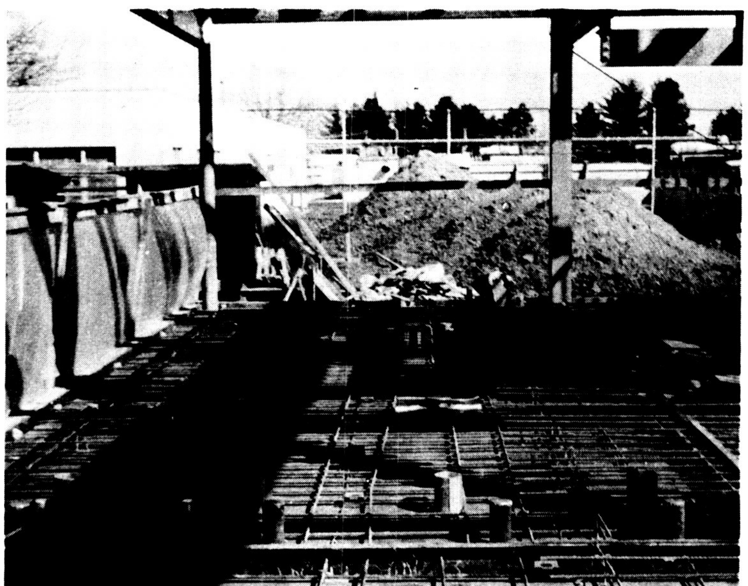
BRICKWORK ON FRONT OF BUILDING



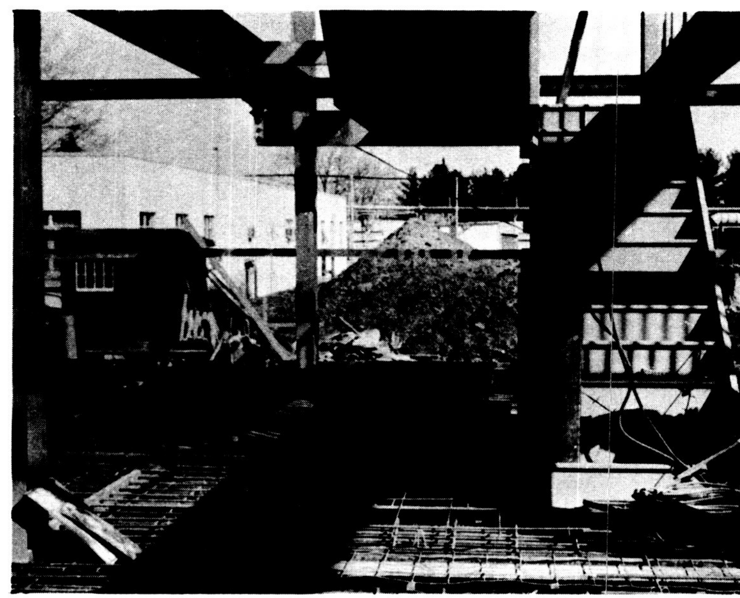
CONCRETE BLOCK NORTH WALL NEARS COMPLETION



FIRST FLOOR REINFORCING STEEL

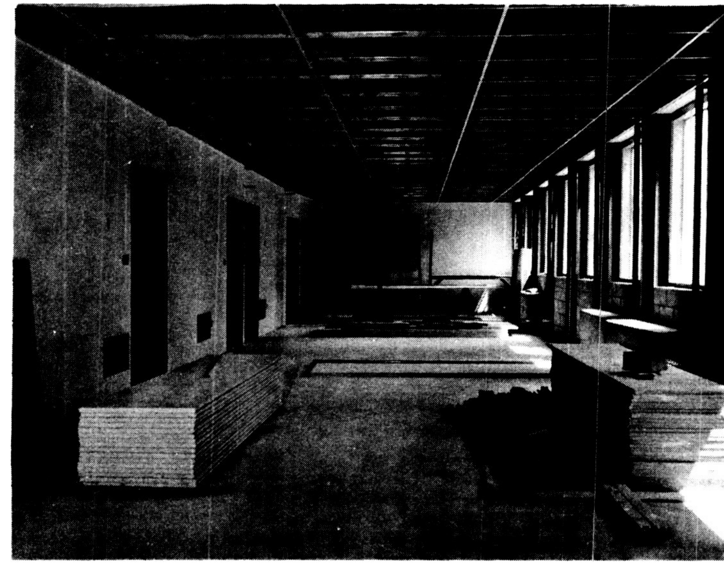


FIRST FLOOR REINFORCING SHOWING
SLEEVES FOR MECHANICAL SERVICES

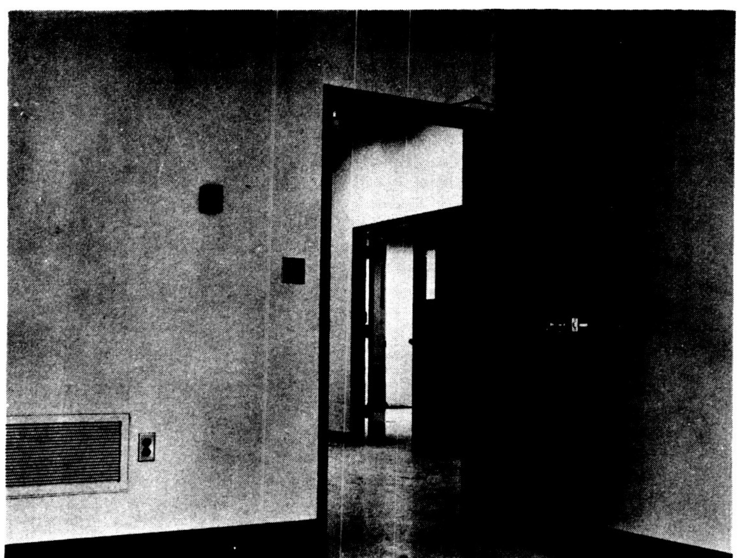


FIRST FLOOR REINFORCING SHOWING
STAIRS ON WEST END

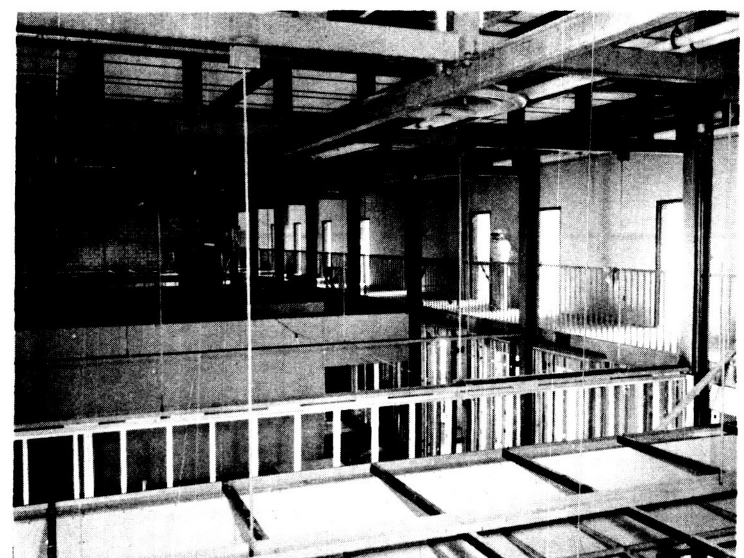
POURING CONCRETE IN FIRST FLOOR



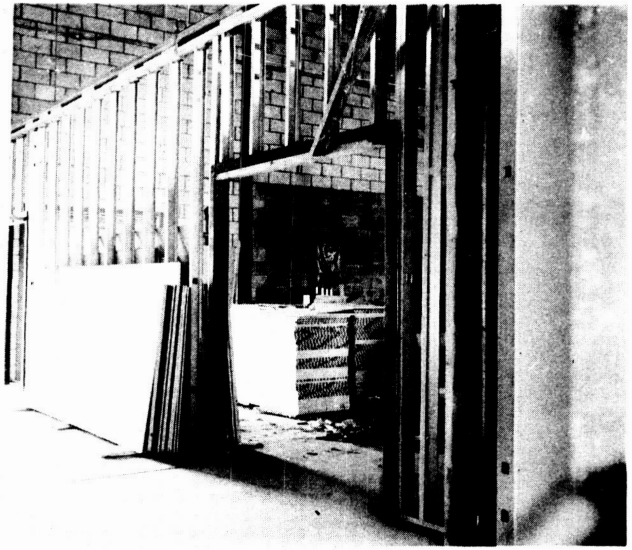
INTERIOR PARTITIONING



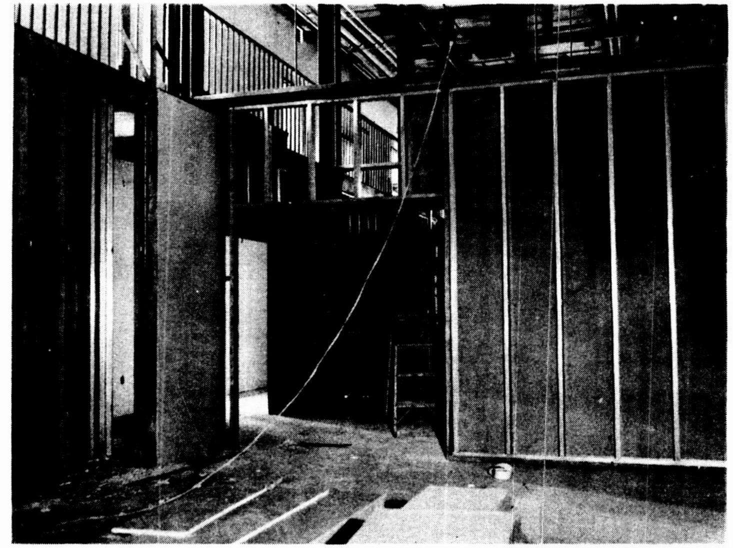
INTERIOR PARTITIONING



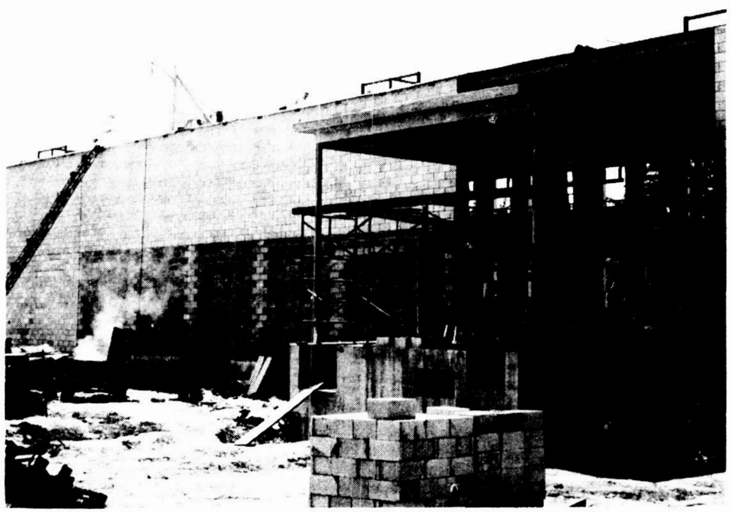
INTERIOR LABORATORY PARTITIONS VIEWED FROM MEZZANINE LEVEL SHOWING VIERENDEEL TRUSSES



INTERIOR LABORATORY PARTITIONS

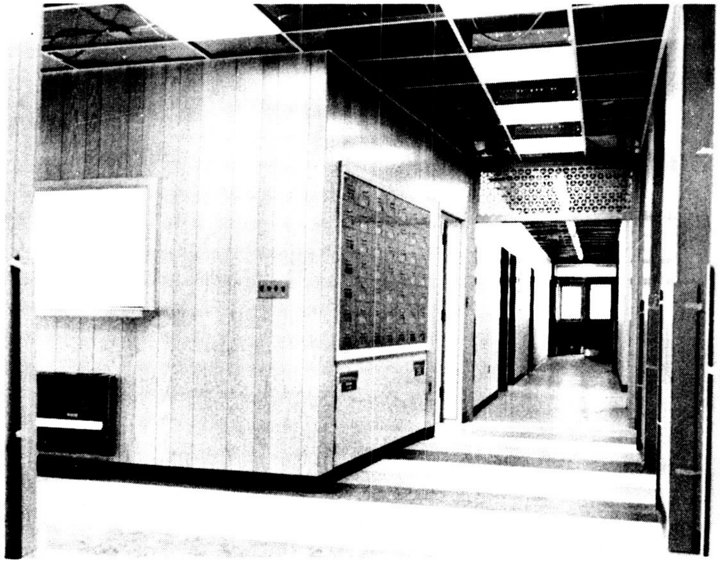


INTERIOR LABORATORY PARTITIONS

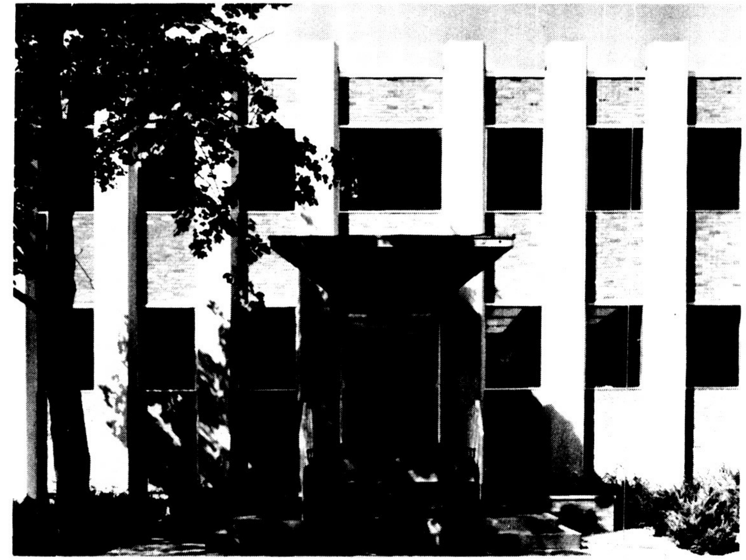


LOADING PLATFORM

STONING THE ROOF

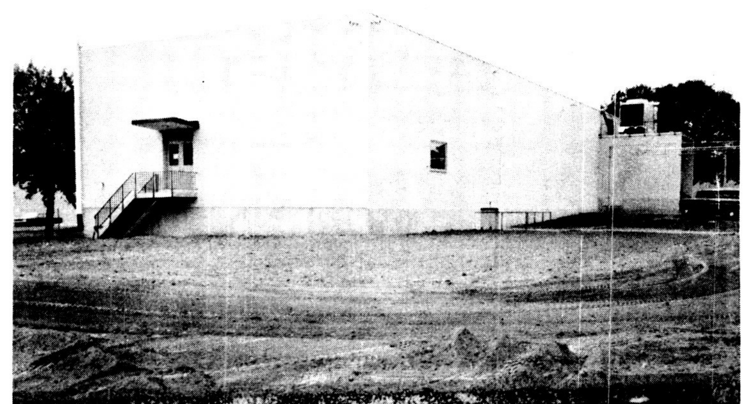


ENTRANCE FOYER SHOWING MAILBOX AND HALL

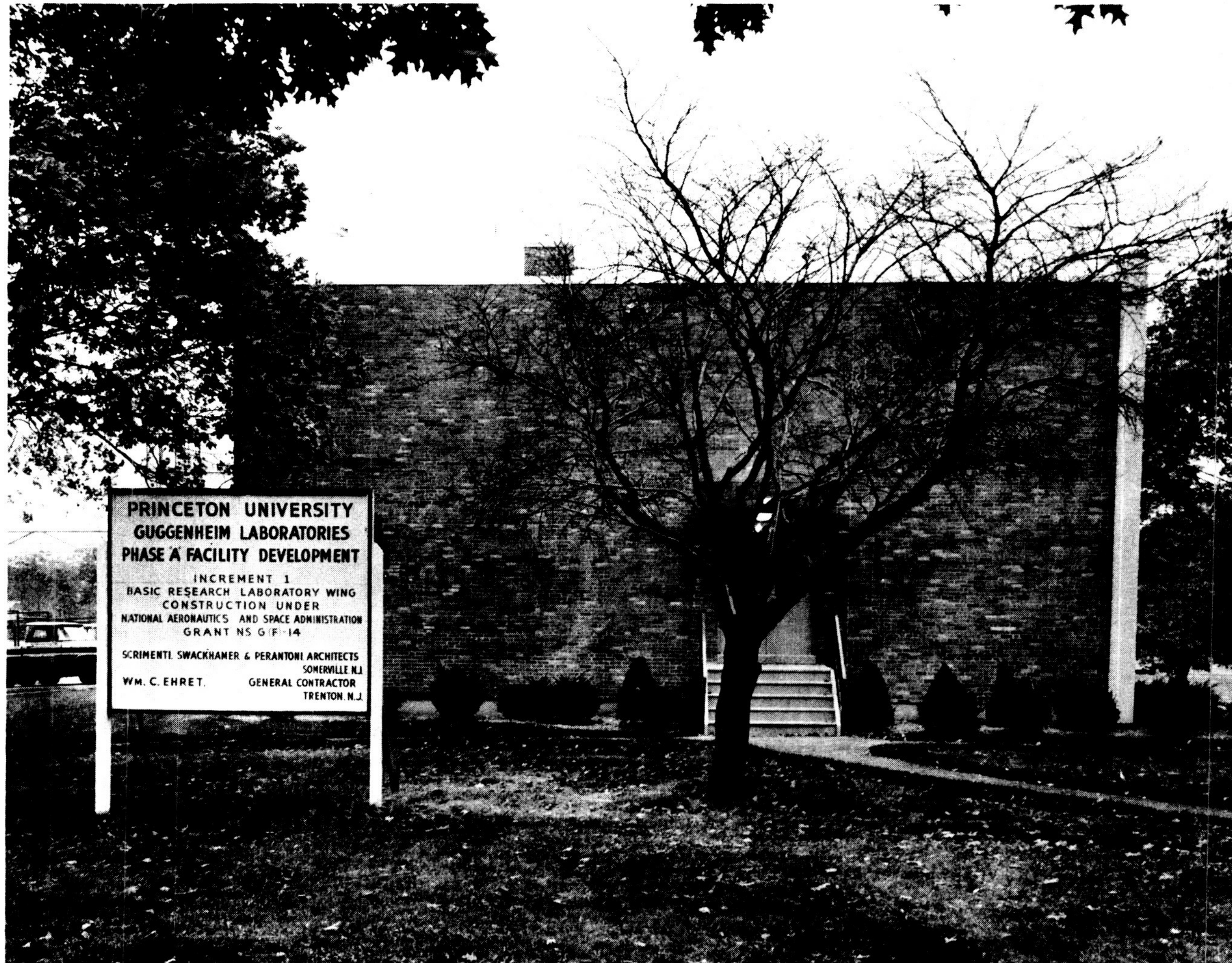


FRONT ENTRANCE

FRONT NEARING COMPLETION

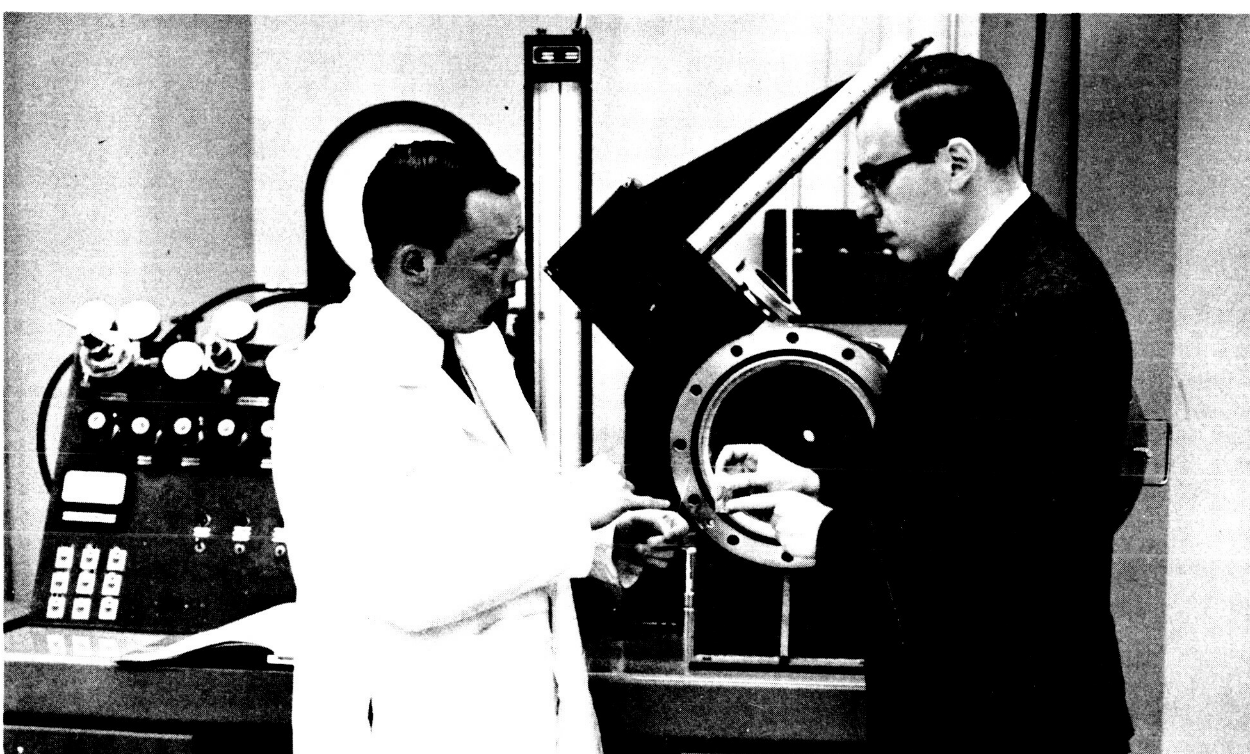


VIEW FROM NORTHEAST NEARING COMPLETION



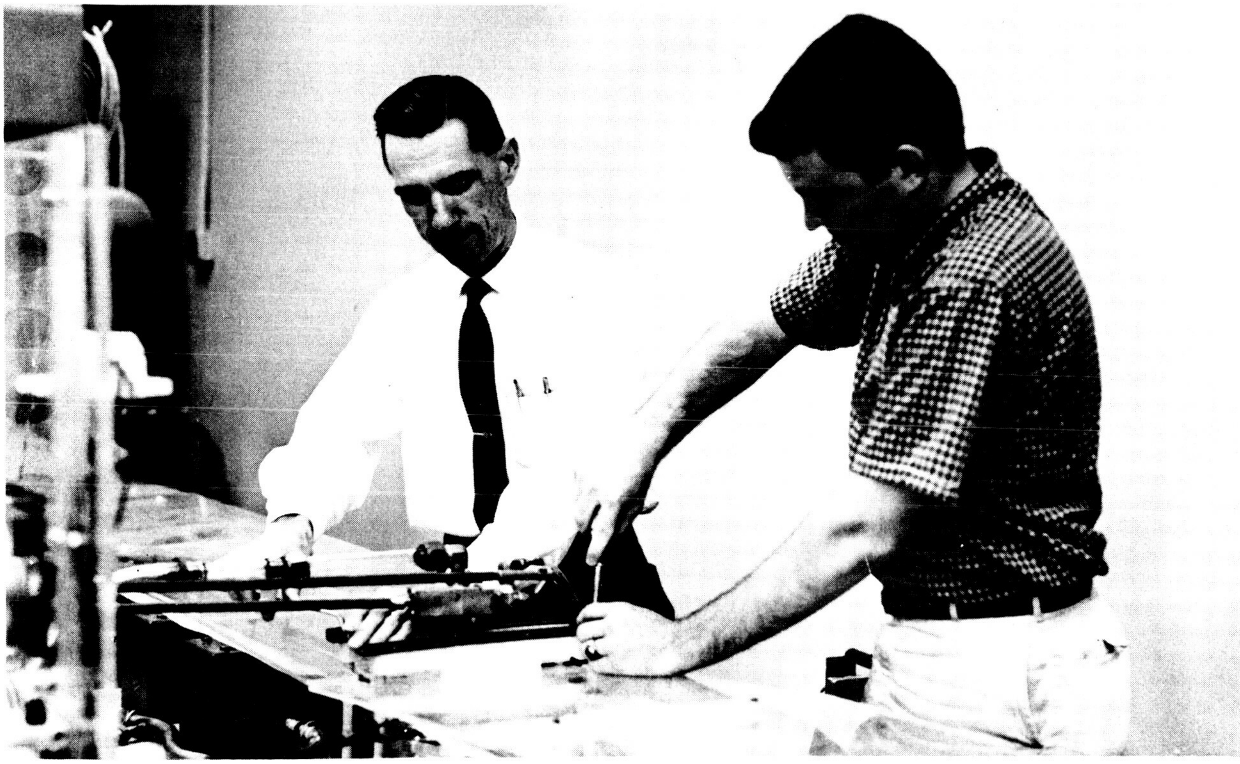
VIEW OF WEST END NEARING COMPLETION

Ph.D student, Arthur Mellor with Advisor, Prof. Irvin Glassman.

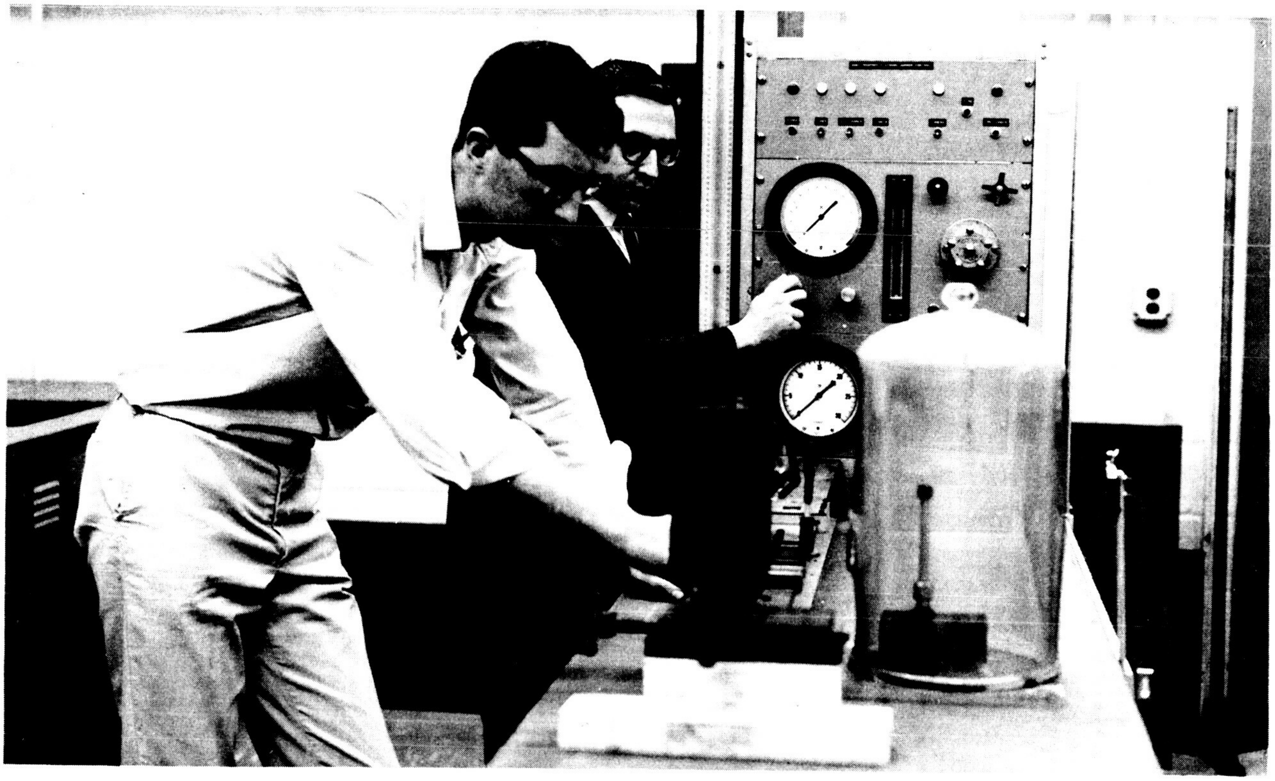


Prof. I. Glassman and A. Mellor in the Metal Combustion Research Laboratory comparing the products of combustion with the original sample.

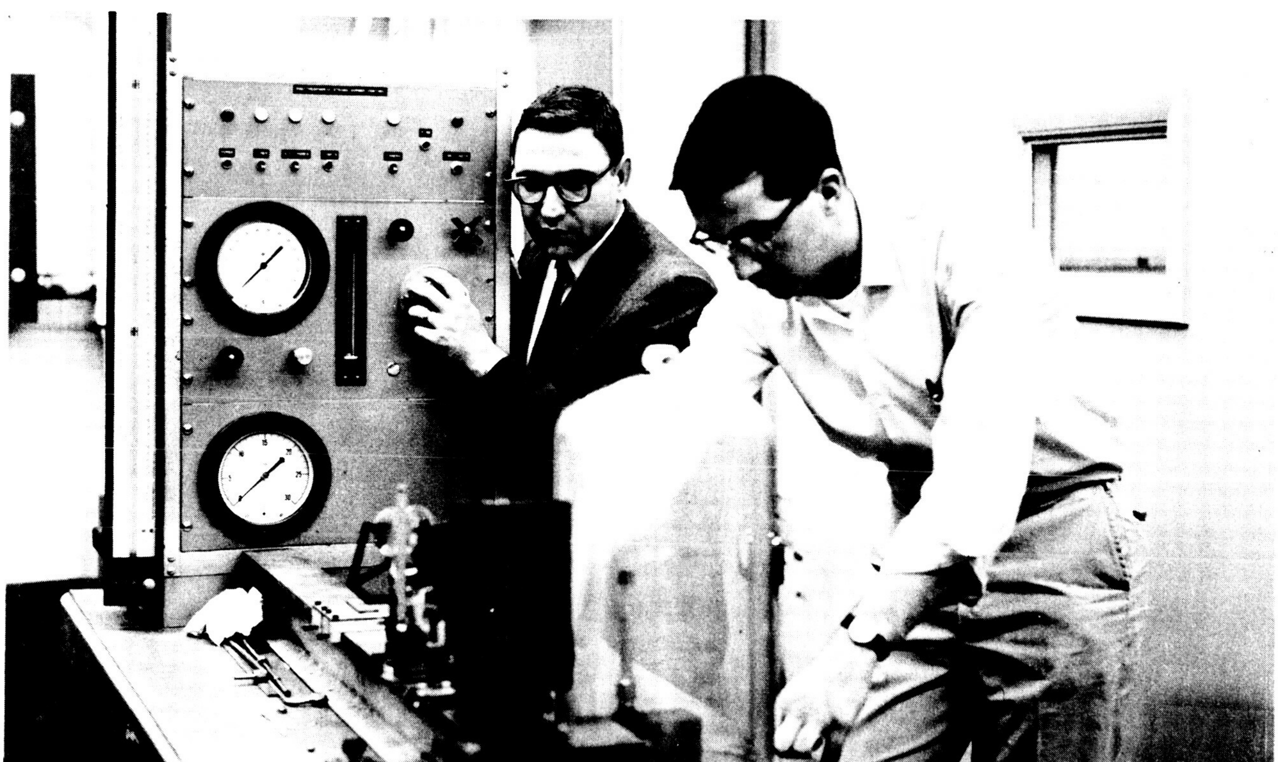
Professor Robert G. Jahn and visiting student, Eberhard Holzhauer examining a pressure transducer in the Electric Propulsion Research Laboratory.



Prof. R. Jahn and student, Alan Eckbreth assembling the Tailored Pulse Pinch Apparatus also in the Electric Propulsion Laboratory.



Research Engineer, Dr. Joseph Wenograd and Ph.D. student Thomas Ohlemiller shown adjusting purge flow for low pressure strand burner in the Solid Propellant Research Laboratry.



Dr. Wenograd and T. Ohlemiller again adjusting purge flow for strand burner.

PROGRAM PARTICIPANTS DR. G. EDWARD PENDRAY, REPRESENTING THE GUGGENHEIM FOUNDATION, DR. HOMER E. NEWELL, NASA ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS, PROFESSOR COURTLAND D. PERKINS, CHAIRMAN OF THE DEPARTMENT OF AEROSPACE AND MECHANICAL SCIENCES, PRESIDENT ROBERT F. GOHEEN, DR. RAYMOND L. BISPLINGHOFF, NASA ASSOCIATE ADMINISTRATOR FOR ADVANCED RESEARCH AND TECHNOLOGY AND DEAN JOSEPH C. ELGIN OF THE SCHOOL OF ENGINEERING AND APPLIED SCIENCE.

LEFT TO RIGHT - PROFESSOR C. D. PERKINS, CHAIRMAN OF THE DEPARTMENT OF AEROSPACE AND MECHANICAL SCIENCES, PRESIDENT ROBERT F. GOHEEN, AND DEAN JOSEPH C. ELGIN OF THE SCHOOL OF ENGINEERING AND APPLIED SCIENCE.

FIRST ROW, LEFT TO RIGHT: PROFESSOR M. SUMMERFIELD, PROFESSOR COURTLAND D. PERKINS, CHAIRMAN OF THE DEPARTMENT OF AEROSPACE AND MECHANICAL SCIENCES, PRESIDENT ROBERT F. GOHEEN, AND DEAN J. DOUGLAS BROWN. SECOND ROW, LEFT TO RIGHT: PROFESSOR IRVIN GLASSMAN, PROFESSOR JERRY GREY, MR. J. PRESTON LAYTON OF THE GUGGENHEIM LABORATORIES FACULTY, AND PROFESSOR ROBERT G. JAHN.

LEFT TO RIGHT: MR. J. FRANK PERANTONI, ARCHITECT, MR. GEORGE SEITZ, GUGGENHEIM LABORATORIES BUILDING PROJECT REPRESENTATIVE, DR. JOHN H. WALLACE, JR., ADMINISTRATIVE DIRECTOR OF FORRESTAL RESEARCH CENTER, PRESIDENT ROBERT F. GOHEEN, MR. J. PRESTON LAYTON AND MR. HAROLD E. BURKERT, GUGGENHEIM LABORATORIES BUILDING PROJECT REPRESENTATIVES.

PROFESSOR COURTLAND D. PERKINS ADDRESSES THE ASSEMBLED FACULTY AND GUESTS.

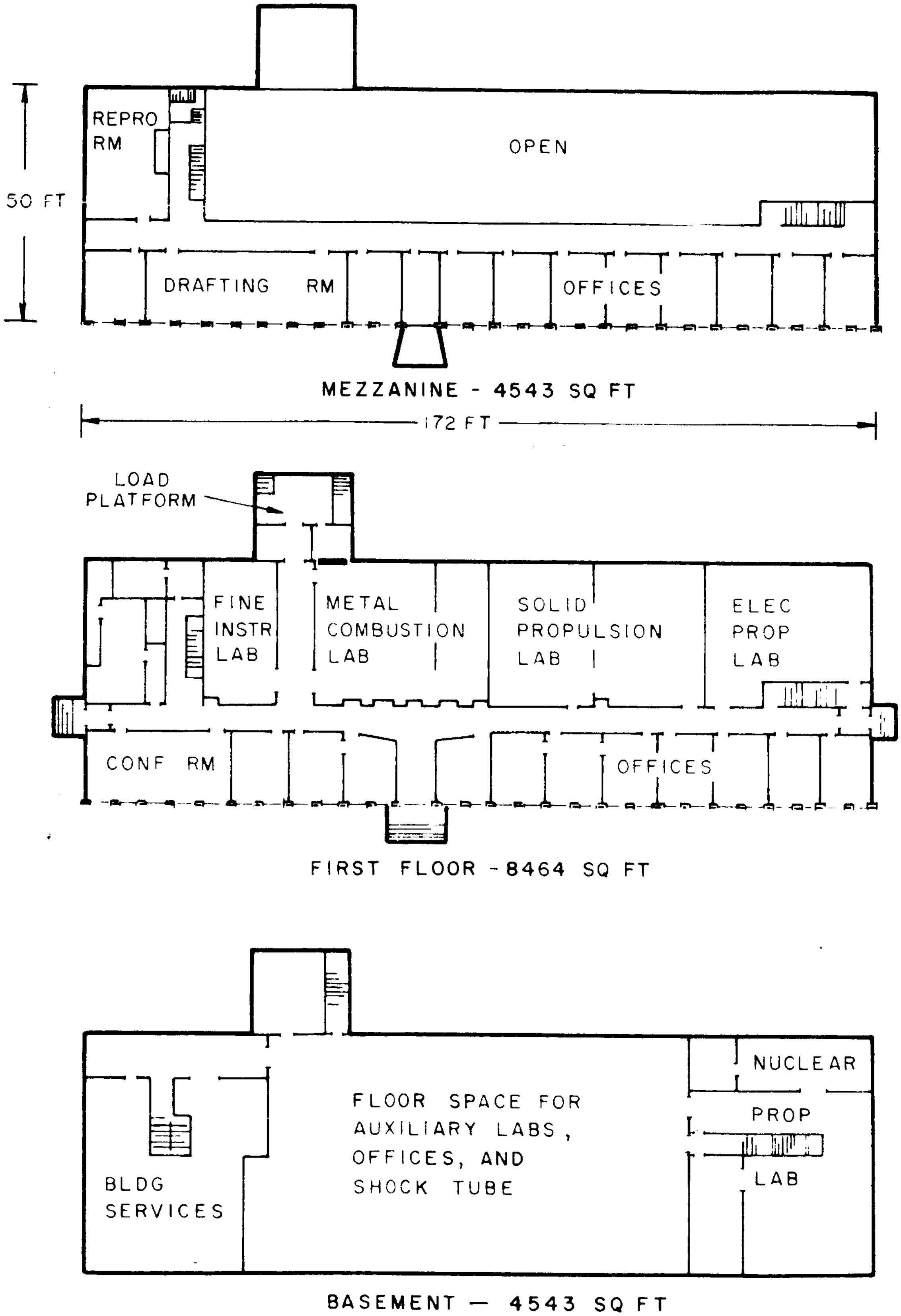
DR. G. EDWARD PENDRAY, REPRESENTING THE GUGGENHEIM FOUNDATION, ADDRESSES THE FACULTY AND GUESTS.

DR. RAYMOND L. BISPLINGHOFF, NASA ASSOCIATE ADMINISTRATOR FOR ADVANCED RESEARCH AND TECHNOLOGY, ADDRESSES THE ASSEMBLED FACULTY AND GUESTS

PRESIDENT ROBERT F. GOHEEN, ACCEPTING THE GOLD KEYS TO THE NEW BUILDING FROM ARCHITECT J. FRANK PERANTONI.

PRESIDENT ROBERT F. GOHEEN ADDRESSES THE ASSEMBLED FACULTY AND GUESTS.

PRESIDENT ROBERT F. GOHEEN AND MR. J. PRESTON LAYTON OF THE GUGGENHEIM LABORATORIES FACULTY CEMENT THE CORNERSTONE IN PLACE, OBSERVED BY MR. HAROLD E. BURKERT, GUGGENHEIM LABORATORIES BUILDING PROJECT REPRESENTATIVE.



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